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NACA

RESEARCH MEMORANDUM

for the

Bureau of Aeronautics, Navy Department

DITCHING TESTS OF A $\frac{1}{18}$-SCALE MODEL OF THE NAVY XP4M-1 AIRPLANE IN LANGLEY TANK NO. 2 AND ON AN OUTDOOR CATAPULT

TED NO. NACA 2362

By

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Langley Field, Va.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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SUMMARY

Tests with a dynamically similar model of the Navy XP4M-1 airplane were made to determine the best way to land the airplane in calm and rough water, to determine its probable ditching performance, and to determine practicable modifications which could be incorporated in the design of the airplane that would improve its ditching characteristics. The results were obtained by making visual observations, by recording longitudinal decelerations, and by taking motion pictures of the landings.

The following conclusions were reached from the results of the tests:

1. The airplane should be ditched at an attitude of 7° with the flaps fully deflected and the wings laterally level. The ditching should be made at as light a weight as possible.

2. In rough water, the airplane should be ditched parallel to the wave crests, unless very strong winds exist, in which case the landing should be made into the wind.

3. Porpoising runs or slight dives will probably occur in calm or rough water unless the tail of the airplane is tripped by a wave crest. If this happens a violent dive will occur.

4. A hydroflap installation on this airplane will reduce decelerations and prevent diving except when the airplane is ditched perpendicular to waves.

INTRODUCTION

The tests were conducted in Langley tank no. 2 and on an outdoor catapult to determine the best way to land the Navy XP4M-1 airplane in calm and rough water, to determine its probable ditching performance, and to determine practicable modifications which could be incorporated in the design of the airplane that would improve its ditching characteristics. These tests were requested by the Bureau of Aeronautics, Navy Department, in their letter of November 22, 1944, Aer-E-23-FAL.

PROCEDURE

Test Methods and Equipment

The apparatus and test procedure were similar to that described in reference 1.

Description of Model

A $\frac{1}{18}$-scale dynamic model of the XP4M-1, shown in figures 1 to 3, was used in the tests. The type of construction used in building the model was similar to that described in reference 2. The model had a wing span of 6.3 feet and an over-all length of 4.6 feet.

A slat was added to the leading edge of the wing to increase the stall angle to approximately that of the full-scale airplane. Scale strength flaps were obtained with friction hinges as shown in figure 4. Failure of the flaps was simulated by the flaps rotating on their friction hinges which were adjusted to obtain the required scale moment.

Test Conditions

(All values given refer to the full-scale airplane)

Gross weight.- The model was tested at weights corresponding to 55,000 pounds (bomb bay and fuel tanks empty) and 80,000 pounds (normal gross weight).

Location of center of gravity.- The center of gravity was located at 22.4 percent of the mean aerodynamic chord and 0.5 inches above the thrust line.

Attitude of thrust line.- The model was tested at attitudes of 1°, 7°, and 13°. The 1° attitude is the three-wheel position and the 13° attitude is near the stall angle. The 7° attitude is an intermediate setting. The attitude angle was measured between the thrust line and the water surface.

Flap deflection.- Tests were made with the flaps set at 0°, 20°, and 40° at scale strength.

Landing speed.- The speeds used are listed in tables I and II. The speeds were such that the model was airborne within ±10 knots of the landing speed calculated from the power-off lift curves that were obtained from the Glenn L. Martin Company.

Conditions of simulated damage.- The model was tested at the following conditions of simulated damage:

(a) Undamaged (fig. 1)

(b) Bomb-bay doors removed to simulate their failure (fig. 2)

(c) Bombardier's windows, nose-wheel doors, forward entrance hatch, bomb-bay doors, radar housing, undersurface of fuselage from aft end of bomb bay to station 680, rear entrance hatch, radome, and jet propulsion intake covers removed to simulate their failure. (See fig. 3(a).) This is the probable condition of damage.

(d) Damage the same as (b), but with the navigator's escape hatch braced open to form a hydroflap. When the hydroflap was braced open at 30° to the thrust line, this condition of damage was designated d-30; when braced open at 45°, the designation was d-45.

(e) Damage the same as (c), but with the navigator's escape hatch braced open to form a hydroflap at 30° (e-30) or 45° (e-45) with the thrust line (fig. 3(b))

Condition of seaway.- The conditions of water surface used were:

(a) Calm water

(b) Wave crests parallel to the flight path, height approximately 3 to 6 feet, length approximately 60 to 120 feet

(c) Wave crests perpendicular to the flight path, height approximately 3 feet, length approximately 60 feet.

RESULTS AND DISCUSSION

Summaries of the results of the tests are presented in tables I and II.

The symbols used in defining the ditching behavior of the model are as follows:

b	deep run - model traveled through the water partially submerged exhibiting a tendency to dive, although the attitude of the model was nearly level
d_1	violent dive - a dive in which the nose of the model submerged as far as the wing and the angle between the water surface and the thrust line was greater than 15°
d_2	slight dive - a dive in which the nose of the model submerged as far as the canopy and the angle between the water surface and the thrust line was less than 15°
h	smooth run - a run in which there was no apparent oscillation about any axis during which the model settled into the water as the forward velocity decreased
p	porpoising - an undulating motion about the transverse axis in which some part of the model was always in contact with the water surface
t	sharp turn - a violent angular motion about a vertical axis, usually caused by one wing tip digging into the water

Photographs showing the characteristic behavior of the model are shown in figures 5 and 6.

Figures 7 and 8 give typical time histories of longitudinal decelerations. Figure 7 shows decelerations obtained at the 7° attitude with the probable condition of damage simulated (with and without a hydroflap). When the hydroflap was not used, the model either porpoised or made slight dives. Figure 7(a) shows the difference in decelerations between these two types of runs. Figure 7(b) shows how the hydroflap decreased the decelerations. Figure 8 shows decelerations obtained at the 1° attitude with failure of the bomb-bay doors simulated. The worst ditching behavior was obtained at this condition.

General Behavior

When the model was ditched in a damaged condition with no ditching aid, either violent or slight dives usually occurred at the 1° attitude, slight dives or porpoising runs at the 7° attitude, and slight dives or sharp turns at the 13° attitude. When no damage was simulated, smooth runs were obtained at the 1° and 13° attitudes while porpoising runs and slight dives occurred at the 7° attitude. When a hydroflap was used, porpoising occurred at all attitudes and conditions tested except when the model was ditched perpendicular to waves. When the model was ditched perpendicular to waves, diving occurred even though a hydroflap was used.

Effect of Attitude

The model frequently dived at each attitude tested except when ditched in the undamaged condition or when ditched in calm water with a hydroflap installed. When damage was simulated, the most severe behavior was at the 1° attitude and the least severe behavior at the 7° attitude. It is recommended that the airplane be ditched at the 7° attitude.

Effect of Flap Deflection

Deflection of the flaps from the 0° to the 20° or the 40° position did not change the type of ditching behavior or vary the average length of landing run more than 1 or 2 fuselage lengths. The average maximum decelerations, however, were noticeably decreased by deflecting the flaps to 40°.

The 40° flap position should be used in a ditching to take advantage of the slower landing speeds and the lower decelerations afforded.

Effect of Weight

Varying the load had very little effect on behavior, but the airplane should be ditched at a light weight to take advantage of the slower speed thus afforded and so possibly lessen the damage caused by the initial impact.

Effect of a Wing-Low Landing

During the tests a number of landings were inadvertently made in which the wings were not laterally level. When this occurred the lower wing tip dug into the water causing a violent turn with an abrupt stop. High longitudinal decelerations were usually obtained in this type of landing. Lateral decelerations were also obtained for a few landings. The lateral decelerations measured were approximately 2g.

Effect of Simulated Damage

In general, the characteristic ditching behavior for this model varied inconsistently from porpoising runs to slight dives (fig. 5) regardless of the simulated damage. However, removal of the bomb-bay doors tended to promote violent dives (fig. 6) whereas, the undamaged model tended to make smooth runs. The most violent dives that occurred in the tests were obtained when the model was ditched at the 1° attitude with the bomb-bay doors removed.

Effect of Hydroflap

In the tests in calm water, when the navigator's escape hatch was braced open at either 30° or 45° to the thrust line to form a hydroflap, all diving was prevented and porpoising runs with lower decelerations were obtained. (See fig. 7.) The decelerations obtained when using the 30° hydroflap were lower than those obtained when using the 45° hydroflap. (See table I.) From this table it can also be seen that tests at condition (d) were made only at the 1° attitude. The purpose of the tests at this damage condition was to see if the hydroflap would prevent the most violent dives obtained in the tests. (See condition (b), 1° attitude.)

Both the 30° and the 45° hydroflaps accomplish their purpose, but the 30° hydroflap is recommended because of the lower decelerations obtained with this setting.

Effect of Seaway

The wave height obtained for a given scale wind velocity at the outdoor catapult was smaller than the corresponding wave height in the open sea for the same wind velocity. Consequently, in the ditching tests, the wave heights are lower than they should be to correspond to the ground speeds at which the model lands. It is possible then, that the ditching behavior obtained at the catapult, in rough water, may be somewhat optimistic.

When ditched parallel to the wave crests, porpoising runs were obtained. When ditched perpendicular to the wave crests, slight dives were usually obtained. Violent dives occurred when the tail of the model hit the leeward side of a wave near the crest. It should be noted that when the model was ditched perpendicular to the wave crests, slight dives were obtained even when the hydroflap was used. This, however, was the only condition in which dives were obtained with the hydroflap.

The airplane should generally be ditched parallel to the waves to prevent diving. However, if very strong winds exist, it is probable that the difficulties of maintaining lateral control will be so great that it will be desirable to land into the wind regardless of the wave direction.

CONCLUSIONS

The following conclusions were reached from the results of the tests:

1. The airplane should be ditched at an attitude of 7° with the flaps fully deflected and the wings laterally level. The ditching should be made at as light a weight as possible.

2. In rough water the airplane should be ditched parallel to the wave crests, unless very strong winds exists, in which case the landing should be made into the wind.

3. Porpoising runs or slight dives will probably occur in calm or rough water unless the tail of the airplane is tripped by a wave crest. If this happens a violent dive will occur.

4. A hydroflap installation on this airplane will reduce decelerations and prevent diving except when the airplane is ditched perpendicular to waves.

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REFERENCES

1. Jarvis, George A., and Kolbe, Carl D.: Ditching Tests of a $\frac{1}{8}$-Size Model of the Navy SB2C-1 Airplane (Army A-25) in Langley Tank No. 2 and on an Outdoor Catapult. NACA MR No. L5L07, 1946.

2. Fisher, Lloyd J., and Steiner, Margaret F.: Ditching Tests with a $\frac{1}{12}$-Size Model of the Army B-26 Airplane in NACA Tank No. 2 and on an Outdoor Catapult. NACA MR, Aug. 15, 1944.

TABLE I.- SUMMARY OF RESULTS OF TESTS IN LANGLEY TANK NO. 2 WITH A

$\frac{1}{18}$-SCALE MODEL OF THE XP4M-1 AIRPLANE

[All values are full scale]

[redacted]

Attitude of thrust line (deg)			1				7				13			
(1) Damage condition	Gross weight (lb)	(2) Flaps (deg)	Knots	Run	Dec.	Remarks	Knots	Run	Dec.	Remarks	Knots	Run	Dec.	Remarks
a	55,000	0					107.9	9	---	p	98.0	6	---	h
		20	116.6	7	---	h	92.9	7	---	p	89.4	7	---	h
		20					92.9	5	---	d_2				
		40	98.0	7	---	h	87.8	7	---	p	81.4	7	---	h
	80,000	40					98.0	7	1.3	h				
b	55,000	0					105.4	2	---	d_2	98.0	4	---	d_1
		0					105.4	4	---	p				
		20	116.0	2	6.0	d_1	92.4	3	---	d_2	89.4	4	---	d_2
		40	96.7	2	---	d_1	85.3	3	---	d_2	81.4	4	---	d_2
	80,000	20	130.6	4	6.0	pd_2								
		20	130.6	5	5.1	p								
c	55,000	0					101.9	4	4.3	p	89.2	3	4.4	t
		0									89.2	4	4.6	d_2
		20	110.5	3	5.2	d_1	95.4	3	5.3	d_2	85.7	3	2.8	t
		20					95.4	4	3.0	p	85.7	3	3.9	d_2
		40	95.5	2	4.4	d_2	89.4	4	3.0	p	81.4	3	3.3	d_2
		40					89.4	2	4.5	d_2	81.4	3	3.4	t
	80,000	40					98.0	4	2.4	pb				
d-30	55,000	20	111.8	4	5.6	p								
		40	95.5	4	2.9	p								
	80,000	20	130.6	7	3.4	p								
		20	130.6	3	5.9	t								
d-45	55,000	40	95.5	3	4.3	p								
e-30	55,000	40	95.5	3	2.8	p	85.4	3	2.4	p	81.4	3	2.8	p
	80,000	40					98.0	5	3.0	p				
e-45	55,000	20	111.8	4	3.8	p								
		40	95.5	5	3.2	p	85.4	3	3.1	p	81.4	3	3.3	p

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(1) Damage condition:
  a. No damage simulated.
  b. Bomb-bay doors removed to simulate their failure.
  c. Bombardier's windows, nose-wheel doors, front entrance hatch, bomb-bay doors, radar housing, undersurface of fuselage from aft end of bomb bay to station 680, rear entrance hatch, radome, and jet propulsion intake covers removed to simulate their failure.
  d. Damage the same as (b), but the navigator's escape hatch was braced open to form a hydroflap at 30°(d-30) or 45°(d-45) with the thrust line.
  e. Damage the same as (c), but the navigator's escape hatch was braced open to form a hydroflap at 30°(e-30) or 45°(e-45) with the thrust line.

(2) Column headings are explained as follows:
  Knots - Speed in knots.
  Run - Length of landing run in multiples of the length of the airplane.
  Dec. - Maximum longitudinal deceleration in multiples of the acceleration of gravity.
  Remarks - Notations under this heading have the following meaning:
    b Ran deeply.
    d_1 Dived violently.
    d_2 Dived slightly.
    h Ran smoothly.
    p Porpoised.
    t Turned sharply.

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TABLE II.- SUMMARY OF RESULTS OF TESTS IN CALM AND ROUGH WATER MADE FROM AN OUTDOOR CATAPULT WITH A $\frac{1}{18}$-SCALE MODEL OF THE NAVY XP4M-1 AIRPLANE

[All values are full scale:
Gross weight - 55,000 pounds
Landing attitude - 7°
Flap deflection - 40°]

Condition of seaway	Calm			Perpendicular waves				Parallel waves			
(1) Damage condition / (2)	Air-speed	Ground speed	Remarks	Air-speed	Ground speed	Wave height	Remarks	Air-speed	Ground speed	Wave height	Remarks
c	81	95	d_2	88 91	88 74	3 3	d_2 d_1	91	98	3	p
e-30	86	91	p	89	51	3	d_2	86 89	96 101	3 6	p p

(1) Damage condition:
c. Bombardier's windows, nose-wheel doors, front entrance hatch, bomb-bay doors, radar housing, undersurface of fuselage from aft of bomb bay to station 680, rear entrance hatch, radome, and jet propulsion intake covers removed to simulate their failure.
e-30. Damage the same as condition c, but the navigator's escape hatch was braced open at 30° with the thrust line to form a hydroflap.

(2) Column headings are explained as follows:
Airspeed — Airspeed in knots.
Ground speed — Ground speed in knots.
Wave height - Wave height in feet.
Remarks - Notations under this heading have the following meaning:
d_1 Dived violently.
d_2 Dived slightly.
p Porpoised.

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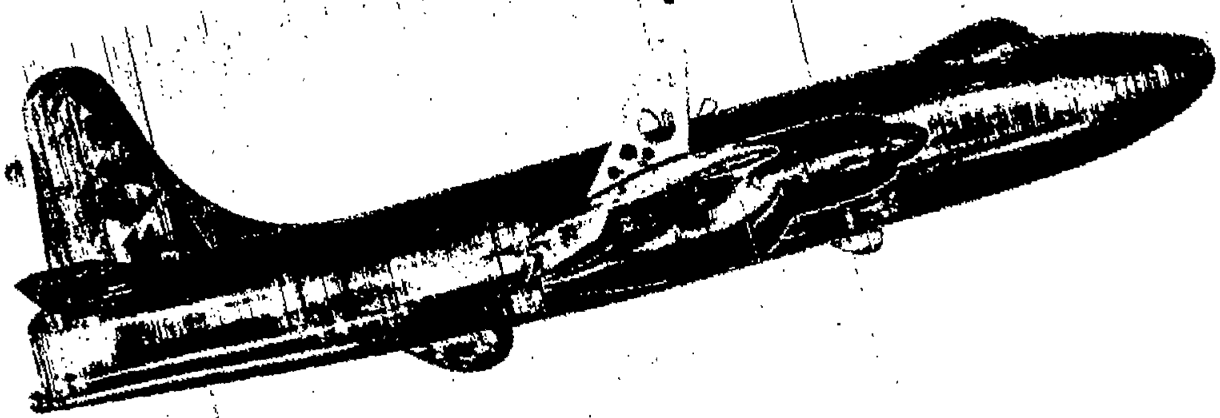

(a) Side view.

Figure 1.- Photograph of a $\frac{1}{18}$-scale ditching model of the Navy XP4M-1 airplane.

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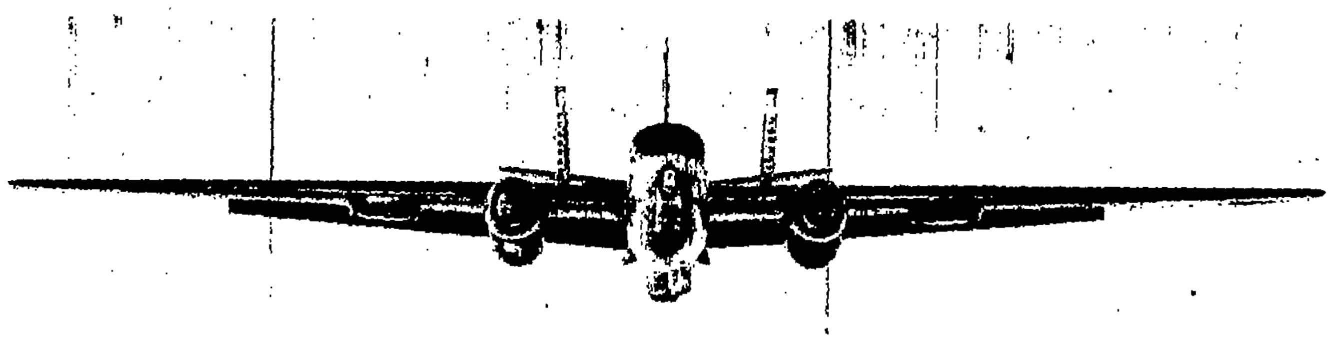

(b) Front view.

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Figure 1.- Continued.

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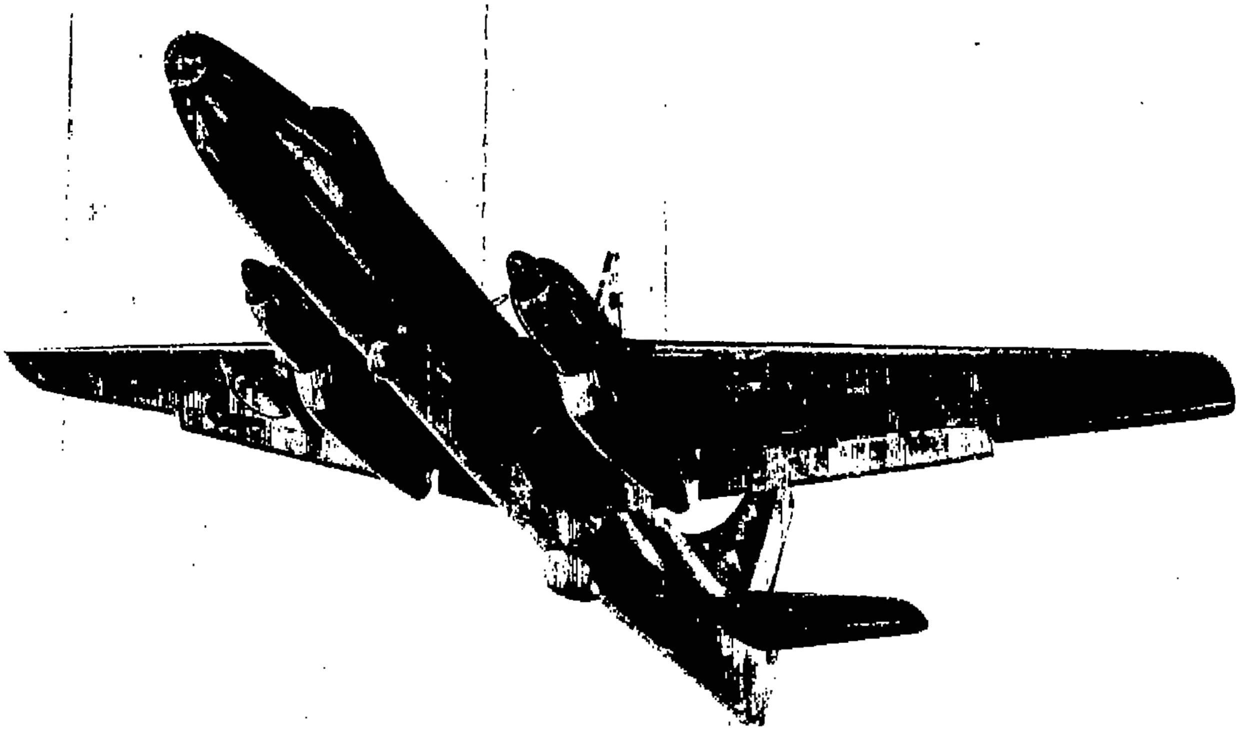

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(c) Three-quarter view.

Figure 1.- Concluded.

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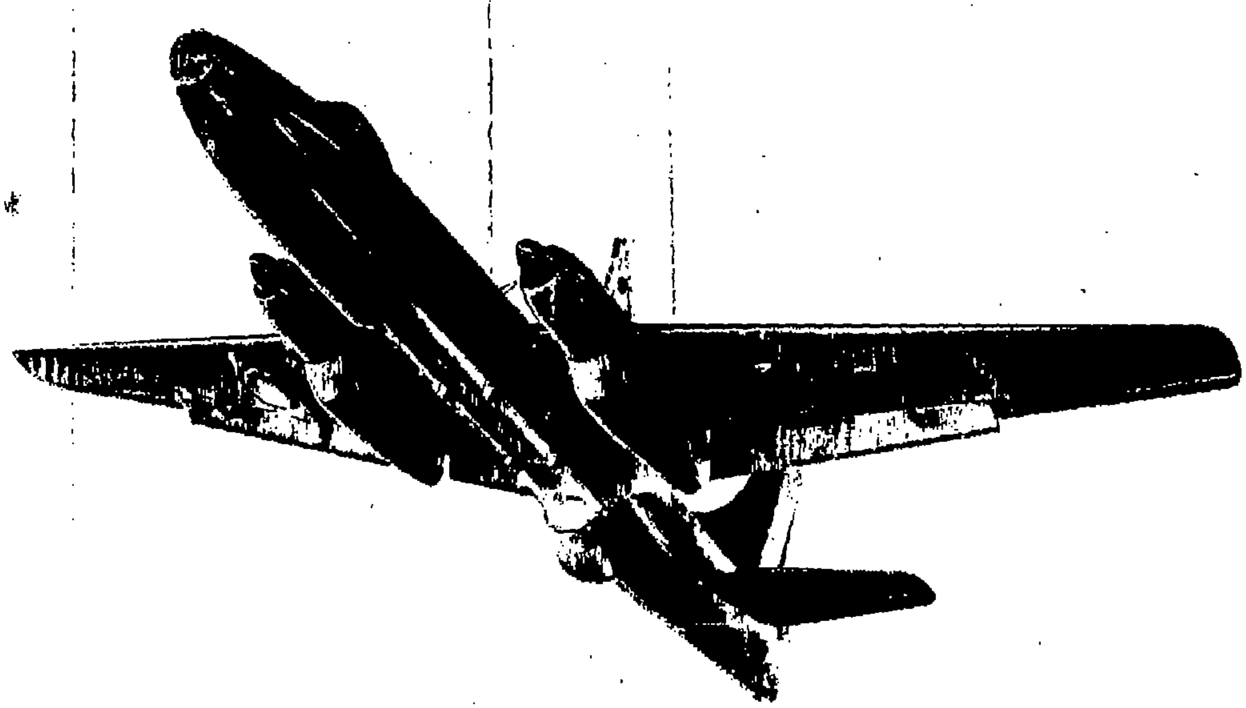

Figure 2.- Ditching model with the bomb-bay doors removed.

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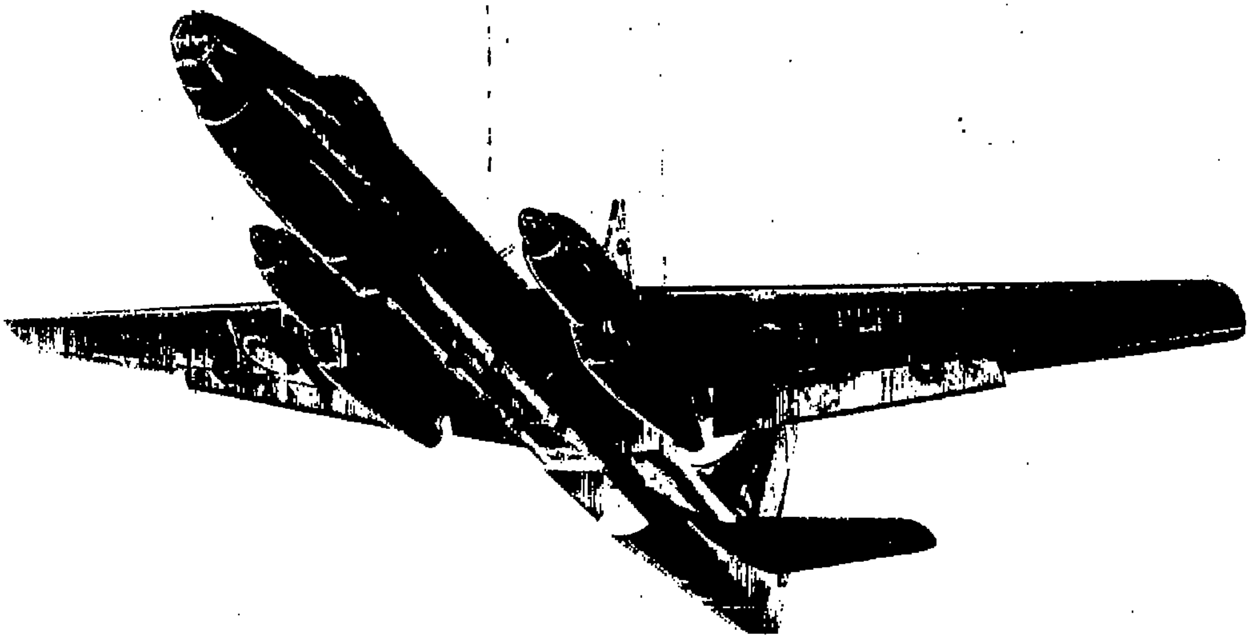

(a). Without hydroflap.

Figure 3.- Ditching model with probable condition of damage simulated.

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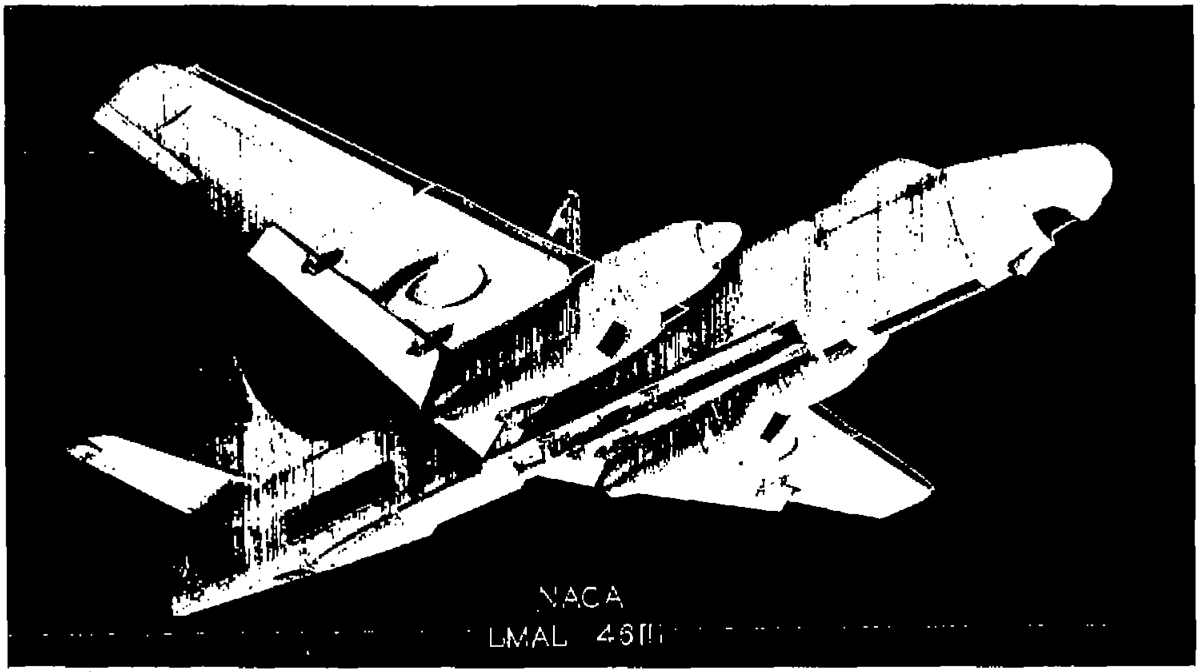

(b) Navigator's escape hatch braced open to form a hydroflap.

Figure 3.- Concluded.

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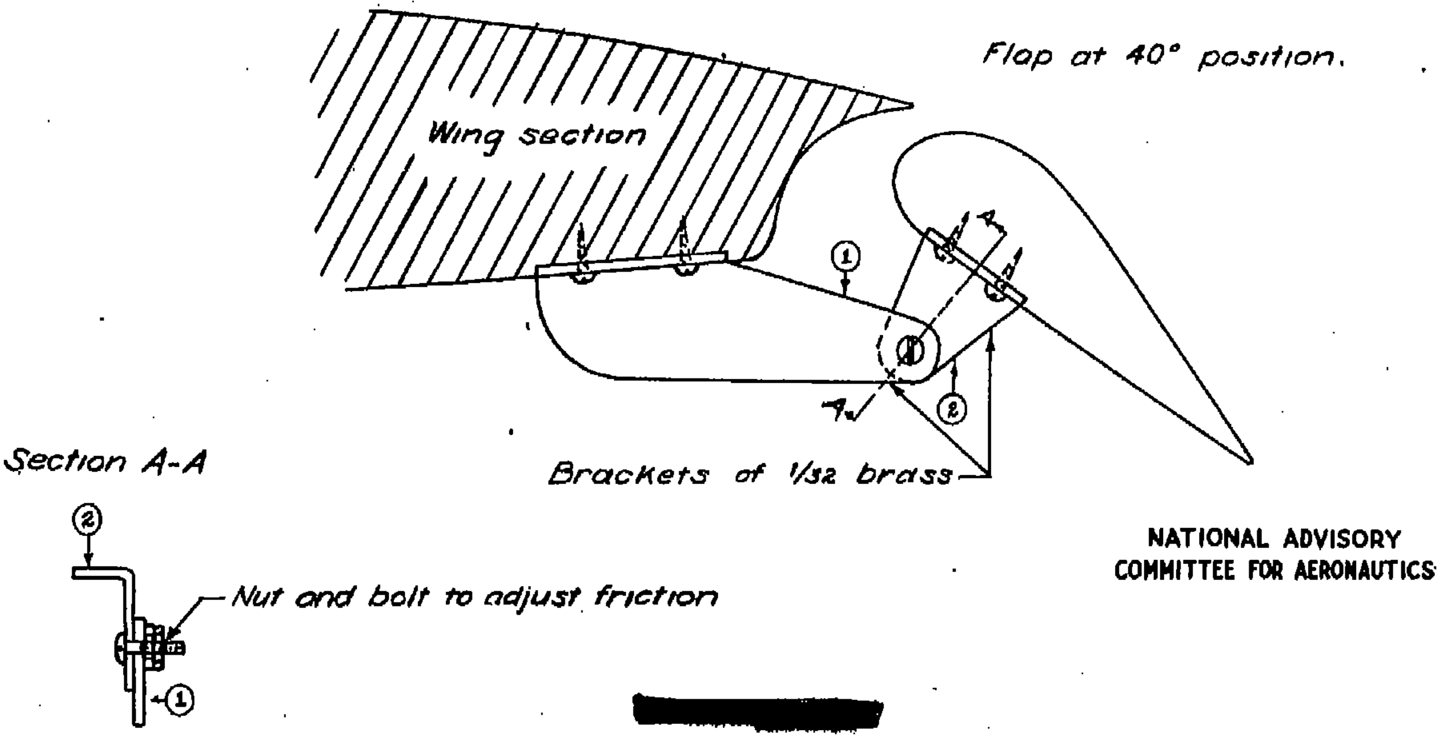

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Figure 4. - Typical friction hinge for scale-strength flaps.

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(a) Porpoising run obtained without hydroflap, speed 89.4 knots.

Figure 5.- Photographs at 0.531 second time interval of XP4M-1 model ditching. Attitude of thrust line, 7°; flaps deflected 40°; gross weight 55,000 pounds, probable condition of damage simulated. (All values are full scale.)

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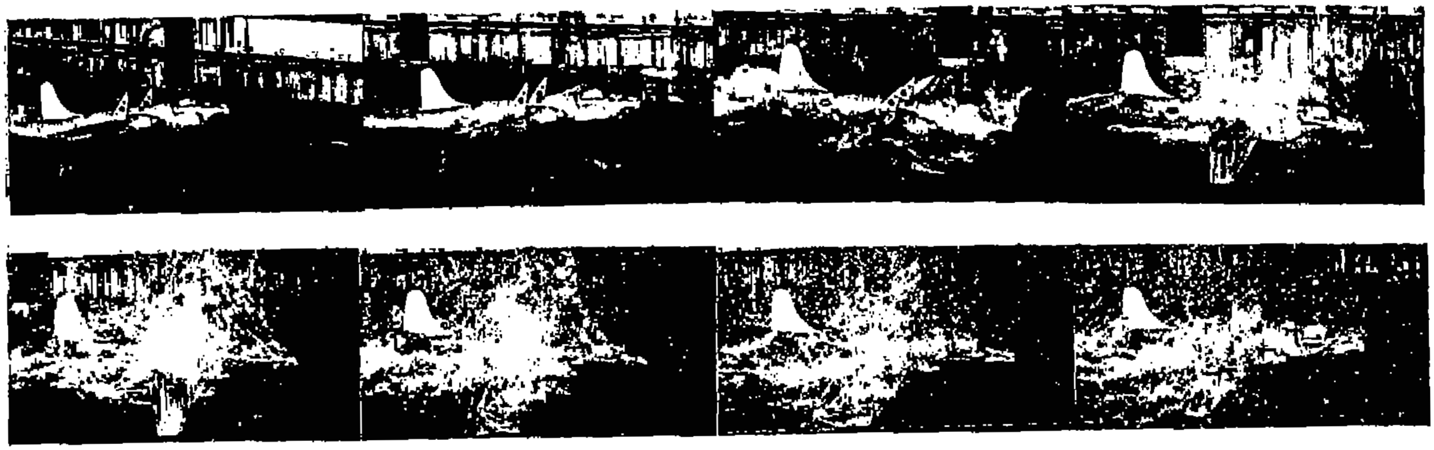

(b) Slight dive obtained without hydroflap; speed 89.4 knots.

Figure 5.- Continued.

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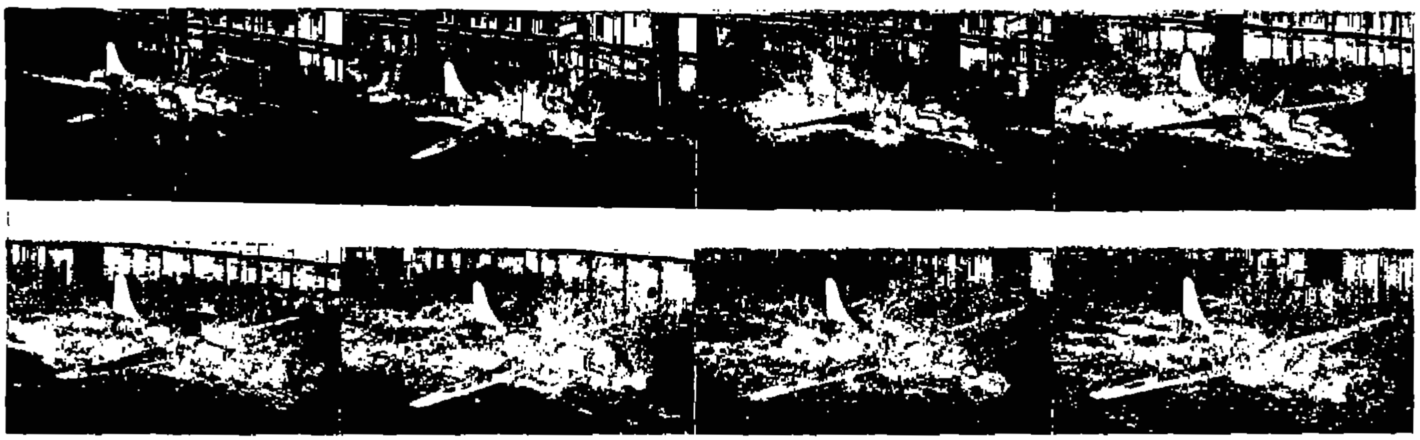

(c) Porpoising run obtained with hydroflap at 30°; speed 85.4 knots.

Figure 5.- Concluded.

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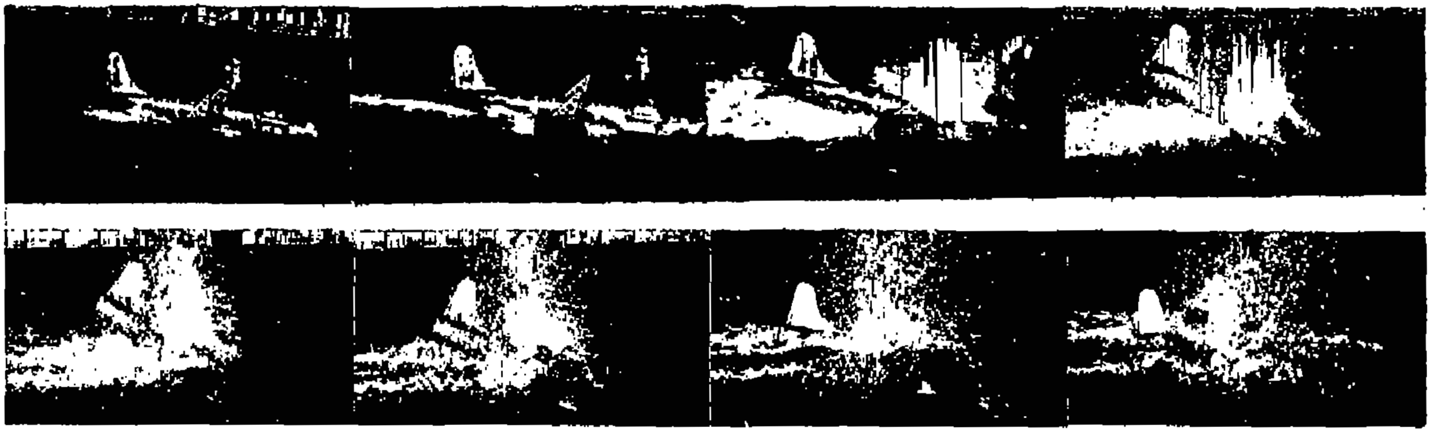

Figure 6.- Photographs at 0.531 second time interval of XP4M-1 model ditching. Attitude of thrust line, 1°; flaps deflected 20°; gross weight 55,000 pounds, bomb-bay doors removed; speed 116.0 knots. (All values are full scale.)

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(a) Attitude, 7°; Speed, 89.4 Knots; Flap deflection, 40°; Without hydroflap.

(b) Attitude, 7°; Speed, 85.4 Knots; Flap deflection, 40°; Hydroflap at 30°.

[redacted]

Figure 7.– Time histories of longitudinal decelerations for ditching tests of a 1/16-size model of a Navy XP4M-1 airplane at 55,000 pounds gross weight in calm water with simulated failure of the bombardier's windows, nose-wheel doors, forward entrance hatch, bomb-bay doors, radar housing, undersurface of fuselage from aft end of bomb bay to station 666, rear entrance hatch, radome, and jet propulsion intake covers. (All values are full-scale.)

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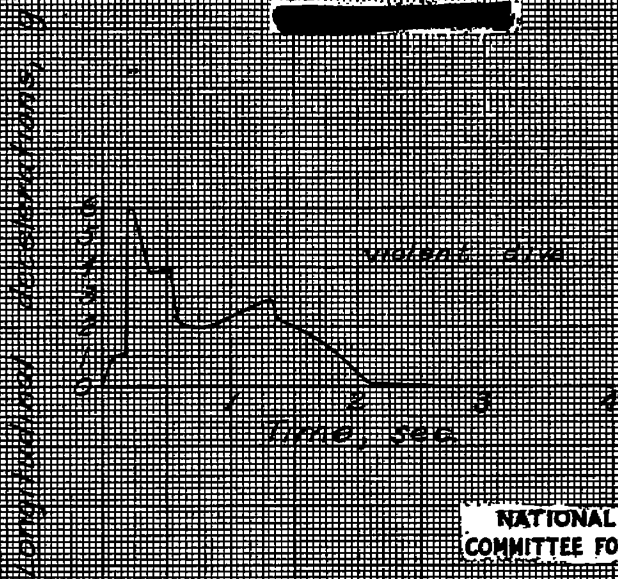

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Figure 8.- Time history of longitudinal decelerations for ditching tests of a 1/16 scale model of a Navy XP4M-1 airplane at 50,000 pounds gross weight in calm water with simulated failure of the bomb-bay doors.
Attitude, 1°; Speed, 116.0 knots;
Flap deflection, 20°
(All values are full-scale)